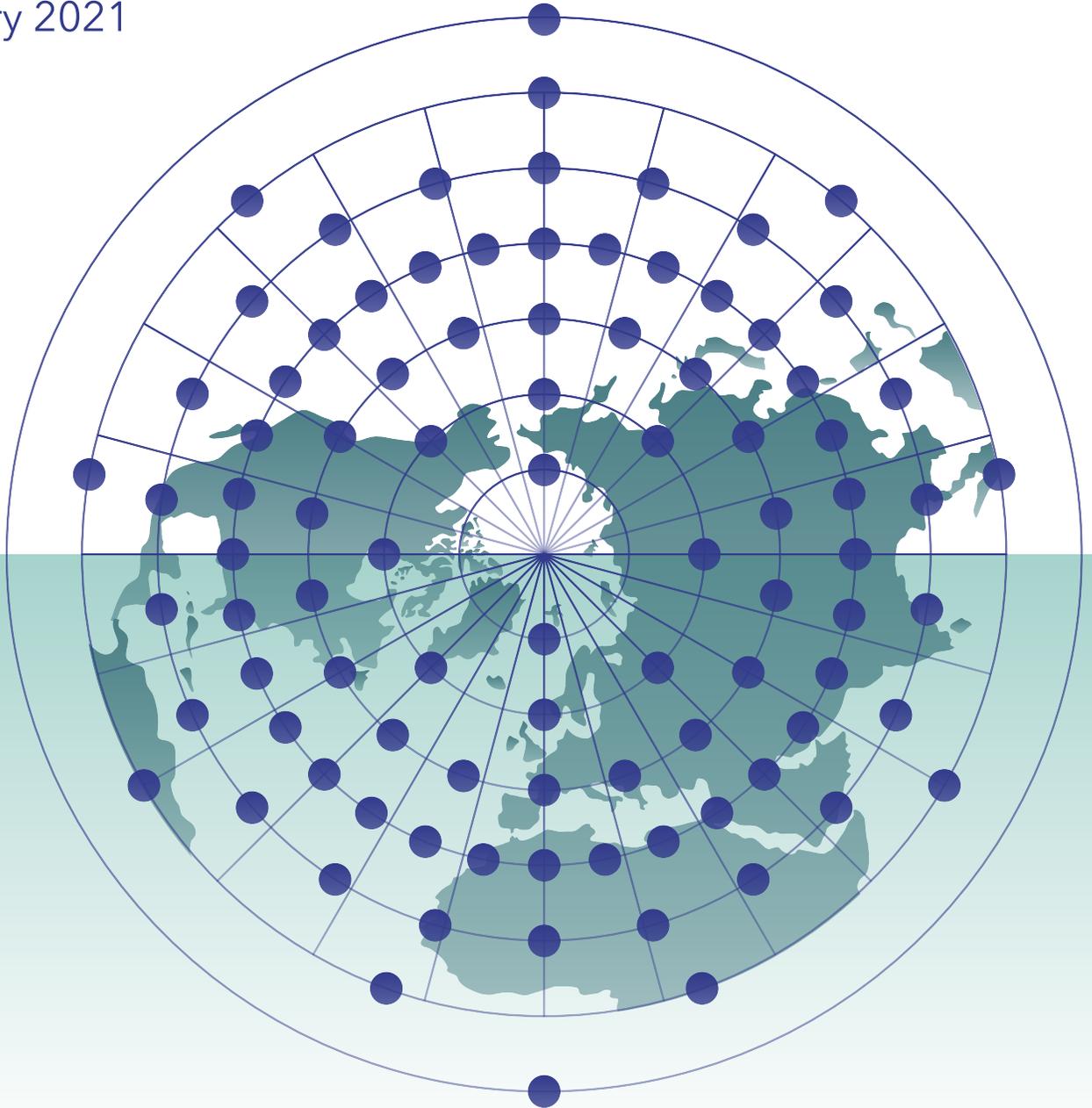


U.S. Advanced Nuclear Energy Strategy

for Domestic Prosperity, Climate Protection, National Security, and Global Leadership

February 2021



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for Domestic Prosperity, Climate Protection, National Security, and Global Leadership**



**PARTNERSHIP for
GLOBAL SECURITY**

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Executive Summary

This is a critical moment for advanced reactors.

Time is of the essence due to the need for U.S. leadership in climate mitigation as well as global norms and markets for commercial nuclear industry. Congress has demonstrated bipartisan support for nuclear innovation for the past several years because of its climate, economic, and security benefits. The incoming Biden administration has set ambitious goals to decarbonize the electric sector by 2035 and the entire U.S. economy by 2050 through a technology-inclusive approach that incorporates nuclear energy. It also has stated its deep commitment to preventing nuclear proliferation, ensuring nuclear security, and promoting safety in future technology.

Existing reactors already provide more than 50 percent of the carbon-free electricity in the United States and the next generation of reactors can be a major part of the climate solution. Congress and the new administration must build on this foundation and rapidly take the actions required to ensure that safe, practical, and secure decarbonization becomes a reality by mid-century. Advanced nuclear energy offers several major benefits:

- **Environmental.** Nuclear energy is carbon-free and does not emit air pollution, which reduces global emissions and saves lives. Advanced reactors can play a major role in deep decarbonization, complementing renewable energy with flexible power generation, providing thermal storage, and supplying non-electric sectors such as heating, hydrogen production, industrial processes, desalination, and direct air capture.
- **Economic.** Advanced reactors are expected to have lower costs than conventional reactors. They come in multiple sizes and with a range of characteristics, making them adaptable for evolving power markets and other sectors. Establishing a new industry can bring high-paying domestic jobs and revitalize industrial communities. The growing demand for carbon-free energy internationally can be met with large and growing reactor exports.
- **Safety and Security.** Advanced reactors have inherent and passive safety features. Advanced reactors enable global commercial market participation, an essential foundation for continued U.S. leadership on international safety, security, and non-proliferation norms. U.S. defense applications can also benefit from advanced nuclear innovation, workforce development, and a larger industrial base.

The U.S. is losing global leadership on nuclear energy due to a slowdown in domestic new builds and growing competition with foreign and State-Owned Enterprises (SOEs). Technological innovation in advanced nuclear energy can re-establish U.S. market leadership. The potential market size for next generation technologies is significant and dozens of American companies are emerging with innovative reactor designs to meet demand.

In close coordination with government, the advanced nuclear industry can build demonstration projects during the 2020s, achieving commercialization, cost competitiveness, and rapid global deployment in the 2030s and beyond. However, U.S. competitors also understand the market and trade opportunities and are developing advanced

reactor designs of their own. Given these tight timeframes, close coordination between industry, government, U.S. allies, and civil society is needed to establish a robust domestic industry. Governments and the advanced nuclear industry should proactively engage now with tribal communities, environmental justice advocates, and labor unions to facilitate their participation in decision making. Supporting state policy is needed to unlock the jobs, tax base, and other economic benefits of advanced reactor demonstration and commercial projects.

Building on bipartisan innovation efforts during the Obama and Trump administrations, the Biden administration and 117th Congress should work together to prioritize advanced reactors to meet American climate, energy, and foreign policy goals.

Personnel is policy and the new administration should appoint nuclear-focused positions in White House offices, ensure that the U.S. Department of Energy's (DOE) nuclear leadership is strong, and continue to nominate knowledgeable and qualified Nuclear Regulatory Commission (NRC) commissioners. The executive branch is best positioned to develop and execute a strategy for advanced nuclear energy exports. By driving interagency coordination among the Department of State, Department of Commerce, DOE, and others, the administration can ensure American foreign policy builds markets for American innovation. The U.S. cannot solve climate change alone and thus efforts should also be made to engage the international community, establish fair competition in global markets, and support countries newly investing in advanced nuclear energy.

Continued bipartisan efforts are needed to support the domestic industry, regulatory reform, and global competitiveness. Additional actions are needed to:

- Ensure sufficient appropriations for federal investment and public-private partnerships during the 2020s
- Continue executive and regulatory efforts to reduce market barriers and modernize regulation for advanced reactors, while protecting public health, safety, and security
- Assist entrepreneurs and coordinate their activities with government research
- Incentivize development of new nuclear fuels while also addressing legacy uranium mining pollution and nuclear waste issues, including investing in cleanup activities and pursuing consent-based solutions

This document provides a strategic framework for the United States to guide domestic and international activities related to advanced nuclear energy. It provides a roadmap to achieving U.S. global leadership on advanced nuclear technologies by leveraging the unique capabilities and roles of government, the private sector, academia, civil society, and U.S. allies.

High-level recommendations:

1. **Utilize public-private partnerships to unleash American innovation.** Government, industry, and private investment can bring research and development (R&D) concepts to demonstration, solving economic, regulatory, and financing challenges of new nuclear technology, while ensuring that high standards of public health and safety are met.

2. **Rapidly commercialize advanced reactors to provide clean energy, deep decarbonization, high-paying jobs, and other economic benefits.** With facilitating policy at the federal and state levels, industry must lead in establishing the cost competitiveness of advanced nuclear energy in multiple sectors.
3. **Incorporate advanced nuclear energy into a broader U.S. climate, innovation, and infrastructure agenda.** Advanced nuclear investment can make affordable, reliable, and clean energy that complements renewables and bolsters energy policy objectives. A whole-of-society effort can create jobs, foster economic growth, promote community development, and modernize our energy system.
4. **Work with U.S. allies and trading partners to compete in global markets for nuclear energy while furthering non-proliferation objectives.** The U.S. and its trading partners should strengthen their position in international nuclear trade, with licensing compatibility facilitating reactor standardization. The U.S. should assure non-proliferation and security of next generation designs by working with allies and international institutions like the International Atomic Energy Agency (IAEA).
5. **Develop a proactive whole-of-government export strategy for advanced reactors.** The U.S. government must support American industry competing with foreign and SOE models by opening foreign markets to American exports. Actions include proactive export agreements, memoranda of cooperation, financing, export control reform, and integrated deals for advanced reactor commercial projects to compete with SOEs.

Foreword

This proposed strategy from the [Nuclear Innovation Alliance](#) and [Partnership for Global Security](#) charts a roadmap for the United States to become the world leader in advanced nuclear technologies, bringing economic, environmental, and security benefits. It is inspired and informed by extensive stakeholder engagement as well as reports, plans, and strategies from multiple groups including industry, government, non-government organizations, environmentalists, and others in the United States and abroad. NIA and PGS would like to thank participants in these processes.

The results of these planning activities build on other reports and strategies examining how to establish advanced reactor leadership. These include:

- Clean Energy 4 Biden’s Chapter “[Advanced Reactors: Pathways to Demonstration and Commercialization](#)”
- DOE’s Nuclear Fuel Working Group’s “[Strategy to Restore American Nuclear Energy Leadership](#)”
- [Canada’s SMR Roadmap](#)
- United Kingdom’s “[Power our Net Zero Future](#)”

The following organizations endorse the general objectives and recommendations of this strategy:

- American Nuclear Society
- Bipartisan Policy Center
- Center for Climate and Energy Solutions
- ClearPath
- Energy Innovation Reform Project
- Good Energy Collective
- Nuclear Engineering Department Heads Organization
- Third Way

Research Acknowledgments:

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Glossary

ARPA-E – Advanced Research Projects Agency – Energy

ARDP – Advanced Reactor Demonstration Program

BRI – Belt & Road Initiative

CEM – Clean Energy Ministerial

COP – Conference of the Parties

DFC – U.S. International Development Finance Corporation

DOE – U.S. Department of Energy

EXIM – Export-import bank

FOCD – Foreign Ownership, Control, or Domination

GIF – GEN IV International Forum

HALEU – High-assay low-enriched uranium

IAEA – International Atomic Energy Agency

IGA – Intergovernmental agreements

IRP – Integrated resource planning

LWR – light water reactor

NASA – U.S. National Aeronautics and Space Administration

NCMOU – Nuclear Cooperation Memoranda of Understanding

NDAA – National Defense Authorization Act

NEA – OECD Nuclear Energy Agency

NNSA – U.S. National Nuclear Security Administration

NRC – U.S. Nuclear Regulatory Commission

OECD – Organization for Economic Cooperation and Development

PR&PP – Proliferation Resistance and Physical Protection

R&D – Research and development

SMR – Small modular reactor

SOE – State-owned enterprise

TRISO – tri-structural isotopic fuel

UNFCCC – U.N. Framework Convention on Climate Change

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1. Introduction: The Promise of Advanced Reactors

Conventional nuclear power plants are the backbone of American clean energy generation, providing about 20% of total U.S. electricity and more than 50% of its carbon-free electricity. Even with recent growth in wind and solar power, nuclear energy still provides more carbon-free electricity nationwide than all other sources combined. Internationally, nuclear energy is similarly important, providing 10% of global electricity. However, high costs and construction issues limit new construction in many countries. Climate mitigation requires significant amounts of clean energy by mid-century and a revitalization of the nuclear sector is needed to ensure it can continue its contribution.

The United States is meeting the challenge in a typically American way: with entrepreneur-led nuclear innovation, supported by government policy. Dozens of U.S.-based companies are designing advanced nuclear reactors, all seeking to develop clean energy technology for domestic use and export. Nuclear energy offers a carbon-free energy source that is reliable and safe. It provides jobs, reduces air pollution, and offers great potential to support global decarbonization at scale.

In 2018, the DOE and National Aeronautics and Space Administration (NASA) demonstrated a fast microreactor, Kilopower, the first novel U.S. reactor designed, built, and operated in decades. In 2020, the *Akademik Lomonosov* entered service and featuring the first widely recognized small modular reactor, underscoring Russia's intent to compete in the [global advanced reactor market](#).

During the 2020s, multiple U.S. government and American commercial projects are on track to commence operations. The federal government is pursuing many advanced reactor projects:

- The [Versatile Test Reactor](#) to support research and industry
- [Two](#) reactor projects to support defense energy security ([Project Pele](#) and 2019 NDAA [microreactors](#))
- Several space reactors, including a commercially developed reactor for NASA to [flight test on the Moon](#)
- Several research reactors, including the [Transformational Challenge Reactor](#) and [MARVEL](#)

Meanwhile, four commercial projects are now moving towards licensing and construction. Oklo made history in 2020 by submitting the first combined license application to NRC for a non-light-water reactor and hopes to build its first microreactor by the mid-2020s. X-Energy and Terrapower received awards under DOE's [Advanced Reactor Demonstration Program](#) (ARDP) to build demonstration reactors by 2027. NuScale is working with a consortium of Utah municipal utilities to build its Carbon Free Power Project with further support from DOE.

Beyond these, many other American companies, including Terrestrial Energy USA and Ultra Safe Nuclear Corporation, are conducting pre-application activities with the US NRC, arranging first customers, and pursuing demonstration projects. In December 2020, DOE announced risk

reduction awards for Kairos Power, Westinghouse, BWXT, Holtec, and Southern Company to move toward demonstration. DOE also awarded funding to Advanced Reactor Concepts LLC, General Atomics, and MIT to assist the progression of early-phase designs.

Ultimately the success of the advanced reactor industry will depend on technical execution, business models, and private investment. Advanced nuclear energy vendors need a favorable environment for commercialization and innovation supported by domestic and foreign policy. Given the long timeframes for nuclear technology development and the short timeframes for climate action, policy pathways must be developed now. This report provides a U.S. strategic framework to guide activities by industry, civil society, and all levels of government to become a global leader in advanced nuclear energy.

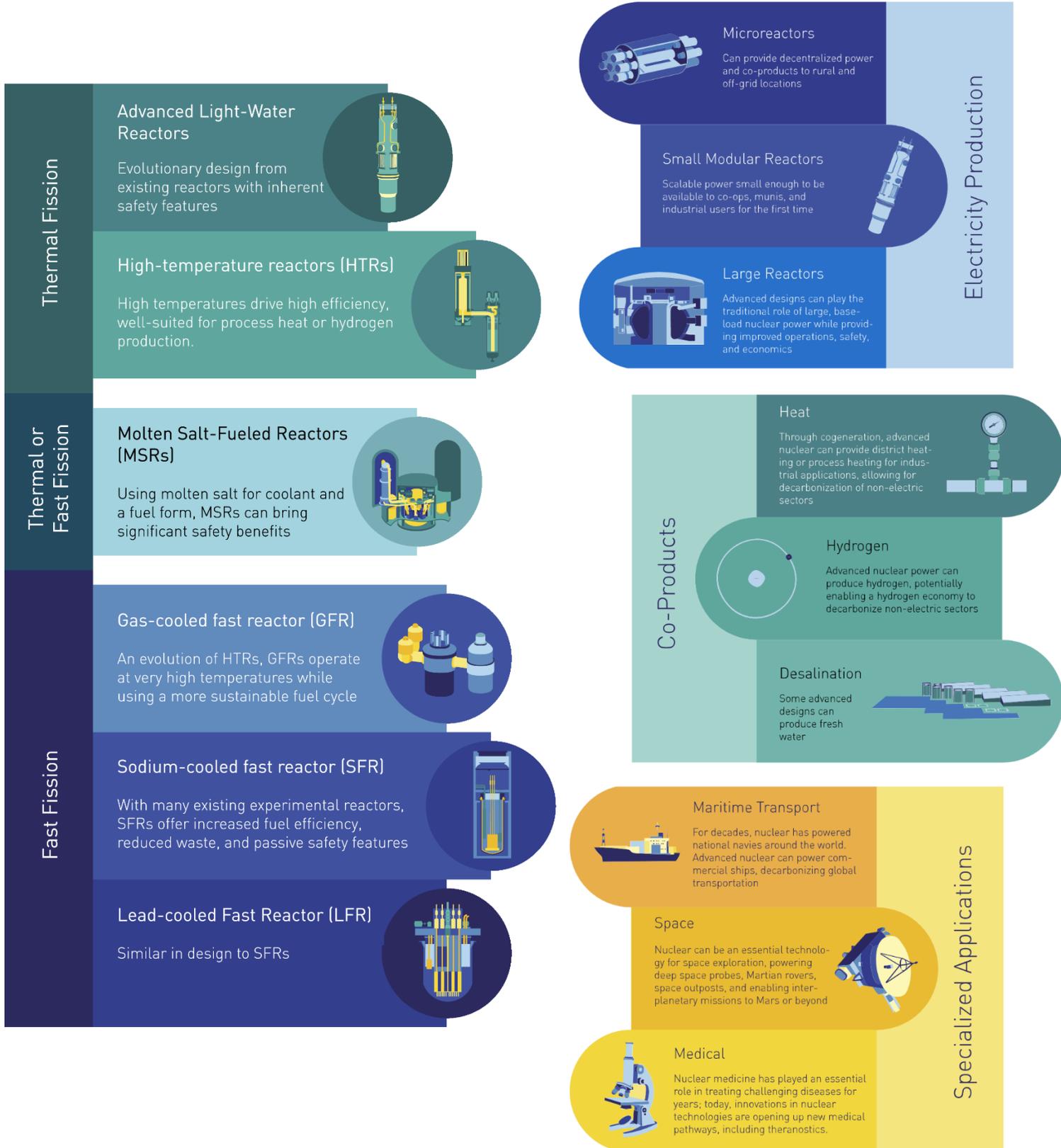
a. Advanced Reactor Technologies

As described in [NEIMA](#), advanced nuclear designs include fission reactors that feature:

1. Inherent or passive safety
2. Lower electricity costs
3. Lower waste yields and/or greater fuel utilization
4. Enhanced reliability
5. Increased proliferation resistance
6. Increased thermal efficiency
7. Ability to integrate into electric and nonelectric applications

Unlike conventional nuclear energy, which provides baseload generation at 1-gigawatt scale or more, next-generation designs are targeted towards the emerging grid and energy systems of the future. They range in size from microreactors less than 10 megawatts electric (MWe) to small modular reactors (up to 300 MWe) and even larger. With smaller plant sizes, they can reach new types of customers, provide [distributed nuclear energy](#), and entail less financial risk due to lower upfront capital costs. They include light-water small modular reactors as well as designs using other fuel cycles and cooling mechanisms. Many advanced reactors feature [flexible](#) characteristics that can balance variable renewable energy and can be integrated with energy storage systems. Critically, advanced designs can support deep decarbonization of non-electric sectors through industrial and [district heating](#), [desalination](#), [hydrogen](#) production, [direct air capture](#), and more. Figure 1 describes advanced reactor innovations and applications.

Figure 1. Advanced Reactor Designs and Applications



b. National and International Goals for Advanced Reactors

Re-establish U.S. leadership in global nuclear energy and exports

Incorporate advanced nuclear energy in domestic and global decarbonization strategy

Set strong international best practices for safety, security, and non-proliferation

Use advanced reactors for sustainable development in emerging economies

Develop and lead an emerging new industry, capturing economic and job benefits

Address environmental and social justice

Build domestic and global framework for rapid commercialization of reactors

Engage the financial sector and encourage business model innovation

Develop consent-based models for spent fuel storage

Maintain existing fleet to support workforce and supply chain development

c. A Societal Strategy for Nuclear Innovation

For advanced reactors to contribute at the global scale needed to avoid the worst climate impacts, a whole-of-society effort is needed. Industry, government, labor, environmentalists, local community leaders, and others must work together to build and support competitive designs and ensure societal benefits through affordable, clean, reliable, and just nuclear energy. Domestic consensus is necessary to enable effective participation in a competitive international landscape. This strategy presents specific as well as general recommendations.

Such efforts should include:

- **Clear administration prioritization and support of nuclear energy domestically and abroad**
- **Federal investment in R&D**
- **Domestic public-private partnerships for R&D through to major demonstration projects**
- **Private sector-led commercialization through cost and business model innovation and private investment**
- **Meeting the needs of labor, environmental justice, and other communities**
- **Creating fair and competitive international markets for nuclear energy**
- **Ensuring the regulatory structure can efficiently and effectively review new and innovative designs while ensuring safety**
- **American foreign policy that prioritizes nuclear energy as part of energy export, global security, and climate diplomacy goals**

Section 2 describes how the Executive branch, Congress, NRC, industry, and stakeholders can work together to establish a robust domestic industry, to commercialize advanced nuclear energy, and to achieve its deep decarbonization and economic benefits.

Section 3 describes how U.S. foreign policy and international activities can create a competitive global market for nuclear energy. By harnessing international institutions and its nuclear trading partners, the U.S. and allies can counter the global influence of Russian and Chinese SOEs. As the Biden administration focuses on climate diplomacy, an advanced nuclear export strategy is central to its success. Due to the nascent nature of advanced nuclear technologies, international advanced reactor guidance is lacking, and the U.S. is well suited to shape the direction of global norms and markets.

2. Domestic Leadership in Nuclear Innovation

The foundation for global leadership is built at home. Recent domestic actions including private sector innovation, government R&D funding, and bipartisan legislation have shown a commitment to the development of advanced nuclear technologies. Sustaining this progress will ensure that American consumers have domestic options for advanced nuclear energy and will provide the basis for exports. Companies, government, and civil society need to work together to create the conditions for success for advanced reactors. This section describes specific actions that each group can take to help develop a competitive and sustainable advanced reactor industry.

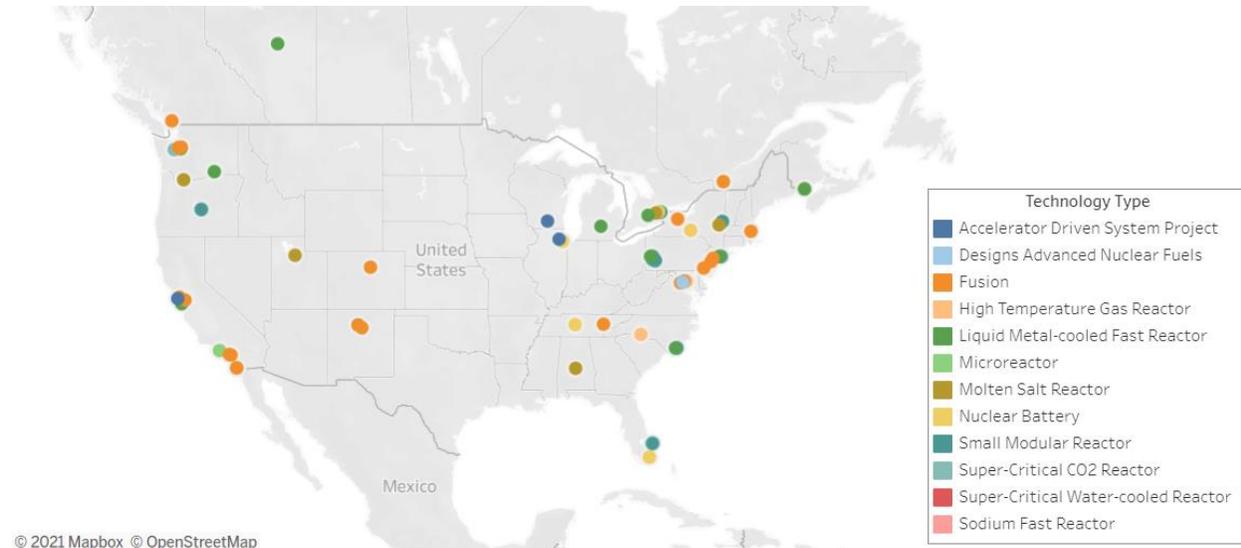
Time is of the essence due to the imperative of climate mitigation and the emergence of foreign competitors for global nuclear markets. Nuclear innovation does not happen overnight, and sustained support is needed to see innovative activities through to completion. Achieving advanced reactor goals requires demonstrations in the 2020s enabling commercialization and construction at scale in the 2030s, and beyond.

Given construction and policy timelines, long-term planning and a national strategy must reduce commercial, regulatory, and other barriers, while ensuring safety and security. Advanced nuclear energy must be able to compete in electricity markets against carbon-emitting sources. Electricity market design must optimize for total system costs while fully valuing all aspects of energy services, including resilience, environmental performance, energy security, and energy diversity. Governments and public power authorities should consider being initial buyers. Beyond electricity, advanced reactors offer decarbonization solutions for many other sectors, such as industrial heating, mining, district heating, desalination, and hydrogen production. Policy and regulation must support such applications and reactor vendors need to engage potential customers and communities to understand their requirements.

a. Industry Design and Business Model Innovation

Central to the success of an American advanced nuclear industry are advanced reactor developers. Responding to the factors that have led to a stagnation in new reactor construction in Organization for Economic Cooperation and Development (OECD) nations, dozens of companies and designs have emerged that seek new approaches to nuclear energy (see Figure 2). These designs could be [cost competitive](#) with grid-supplied electricity, restoring new nuclear construction as a cost- competitive energy option.

Figure 2. North American Advanced Reactor Companies



Source: [Third Way](#)

To achieve market leadership, industry should consider the following recommendations:

- **Identify, engage, and educate potential customers (utilities, industry, communities, specialized) early**
- **Develop new business models for nuclear energy, such as direct power sales, project financing, or other financial innovations from adjacent energy sectors**
- **Address diversity, equity, and inclusion issues to build the most competitive and innovative workforce possible**
- **Create good jobs and ensure that advanced reactor development is a welcome economic benefit for local communities**
- **Provide lower costs and [cost certainty](#) for consumers**
- **Develop a robust supply chain and workforce for advanced reactors**
- **Feature flexible capabilities or strategies and ensure these are known to potential customers**
- **Pursue energy markets beyond the power sector**
- **Ensure reactors are consistent with global security requirements, using methods such as safeguard-by-design and security-by-design**

Beyond these activities, engagement with the financial investment community is needed to unlock private sector capital for innovators. Investors need information regarding nuclear energy's role in future energy markets and features of new designs. Advanced nuclear energy has different characteristics from other energy technologies, and mutual education of investors and developers is needed to match opportunities with investment. Financial innovation and new investors are needed to [keep costs of capital low](#), provide revenue streams, and encourage cost optimization.

b. Federal Policy and Financing to Facilitate Commercialization

Congress and the executive branch should recognize that advanced reactors are still an emerging technology and decisive action is needed to harness the benefits from a new industry. Recent bipartisan legislation has [catalyzed](#) industry innovation and regulatory reform. Nevertheless, continuing legislative and executive action is needed to unlock the full economic potential of advanced nuclear energy. Existing and new Congressional champions should continue bipartisan collaboration to support ongoing appropriations and new legislation.

Achieving leadership in advanced nuclear energy requires legislative action that:

- **Ensures sufficient appropriations for DOE nuclear activities, including the Advanced Reactor Demonstration Program (ARDP), SMR R&D, ARPA-E, NRC, and other nuclear-related activities**
- **Funds multiple demonstration projects with a diversity of designs to ensure American companies lead in the race towards commercialization**
- **Offers government testing platforms and services for industry, including the Versatile Test Reactor, Gateway for Advanced Nuclear Innovation, and National Reactor Innovation Center**
- **Provides appropriate incentives for first-of-a-kind nuclear plants, including tax credits, grants, loan guarantees, and long-term power purchase agreements**
- **Accounts for carbon damages to provide a level field for competition between advanced nuclear energy and fossil fuels**
- **Maintains robust basic R&D funding**
- **Provides support for university research and workforce development**
- **Funds NRC and NNSA to integrate advanced reactors into their missions**

The Executive branch can support research and development, oversee demonstration projects, and otherwise make federal assets available to innovators. **The Biden Administration can allow advanced nuclear energy to play a key role in meeting its climate and energy objectives by:**

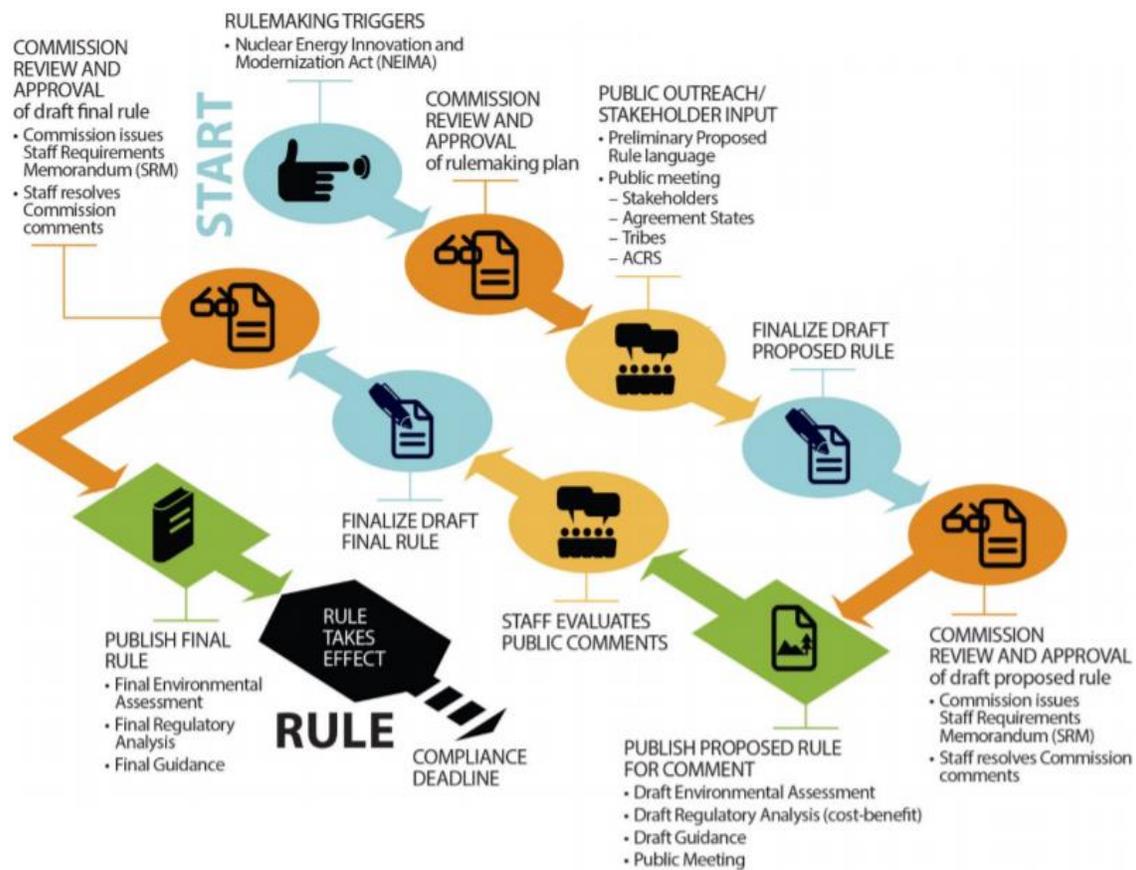
- **Continuing to nominate knowledgeable and qualified DOE officials and NRC Commissioners**
- **Broadening nuclear consideration across agencies, including nuclear staff positions in the White House, National Security Council, and National Economic Council**
- **Ensuring that nuclear technology R&D, demonstration, and commercialization efforts at DOE are predictable, sustained, technology-inclusive, and competitive**
- **Supporting industry-competed awards through the entire cycle of technology development, licensing, and demonstration to enhance chances for successful commercialization**
- **Implementing milestone payment [model](#) options for demonstration projects to maximize chances of successful development and minimize risks to taxpayers**
- **Directing DOE to conduct analysis and applied research on how advanced reactors can supply non-electric sectors to meet deep decarbonization requirements**
- **Conduct further research into low-dose radiation health effects**

c. Regulation for a New Generation of Nuclear Energy

A new generation of nuclear energy requires an appropriate regulatory system. U.S. and other countries' regulatory regimes are often too technology-specific, meaning they are designed around the characteristics of traditional light water reactors. Advanced reactors can be licensed through the existing U.S. regulatory framework under Part 50 and 52 rules implementing the Atomic Energy Act. NuScale received its design certification, Oklo has submitted the first non-light water combined licensed application, and several ARDP awardees will be applying for licenses under the current regime. Nevertheless, the existing framework needs to be adapted to manage the new and diverse characteristics of advanced reactor designs.

Accordingly, regulatory innovation can better enable a new type of nuclear technology while ensuring that high standards of public health and safety are met. The NRC must continue to operationalize risk-informed, performance-based, technology-inclusive regulation per the Nuclear Energy Innovation and Modernization Act ([NEIMA](#)). Licensing should be affordable, certain, and timely to enable the rapid build out of clean nuclear energy while meeting high standards. A new licensing pathway under development, [Part 53, offers a strong start](#) but other regulatory issues must be addressed.

Figure 3. Rulemaking Plan and Timeline for Part 53



Source: [NRC](#)

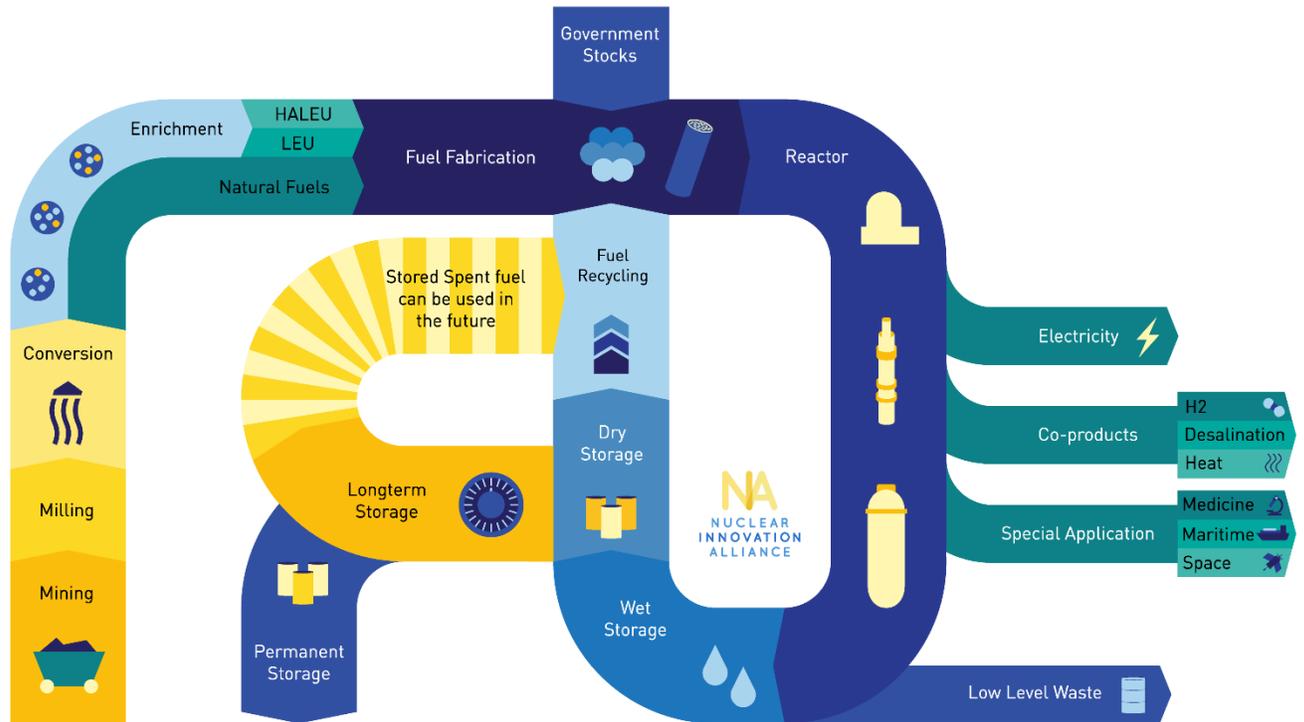
To adopt a regulatory framework tailored to advanced reactors, the Nuclear Regulatory Commission should:

- **Develop a final rule for Part 53 by October 2024**
- **Investigate and address regulatory [challenges](#) for non-electric applications, including transportable reactors**
- **Proactively communicate staff and resource requirements to meet these objectives to Congress**
- **Consider how to reduce application times, redundant processes, and paperwork while maintaining rigorous standards and requirements**

d. Reevaluating the Nuclear Fuel Cycle

Nuclear fuel is the basis of nuclear energy and many innovations in advanced reactor designs are based on [new types of nuclear fuel](#). As reactor developers pursue new reactor designs, they require fuel cycle innovations to provide new materials or fuels such as high assay low enriched uranium (HALEU), salts, tri-structural isotopic fuel (TRISO), and thorium (see Figure 4). The importance of these innovations is underscored by the two recent ARDP demonstration awards, which both contained fuel supply as part of the projects. The need for new fuel manufacturing capabilities offers an opportunity for the U.S. to revitalize its fuel industry through modernization and expansion, supporting American job growth. At the same time, nuclear waste policy is deadlocked. The country needs new approaches to spent nuclear fuel, with potential options including fuel utilization efficiency improvements, fuel recycling innovations, and interim waste storage. Ultimately, the U.S. will need consent-based siting to develop solutions for long-term storage.

Figure 4. Advanced Nuclear Energy Fuel Cycle Options



Addressing fuel and waste issues requires a whole-of-society approach from government, industry, and stakeholders. The global nuclear landscape has changed considerably since Congress last addressed fuel and waste cycle issues. The opportunities provided by advanced nuclear reactors should prompt a reconsideration of front-end and spent fuel strategies. Governments and industry should improve performance going forward related to uranium mining, government waste, and local control, especially for tribal and disadvantaged communities. They also must continue to address legacy issues.

To reimagine the nuclear fuel cycle for advanced reactors, Congress, regulators, industry, and civil society can:

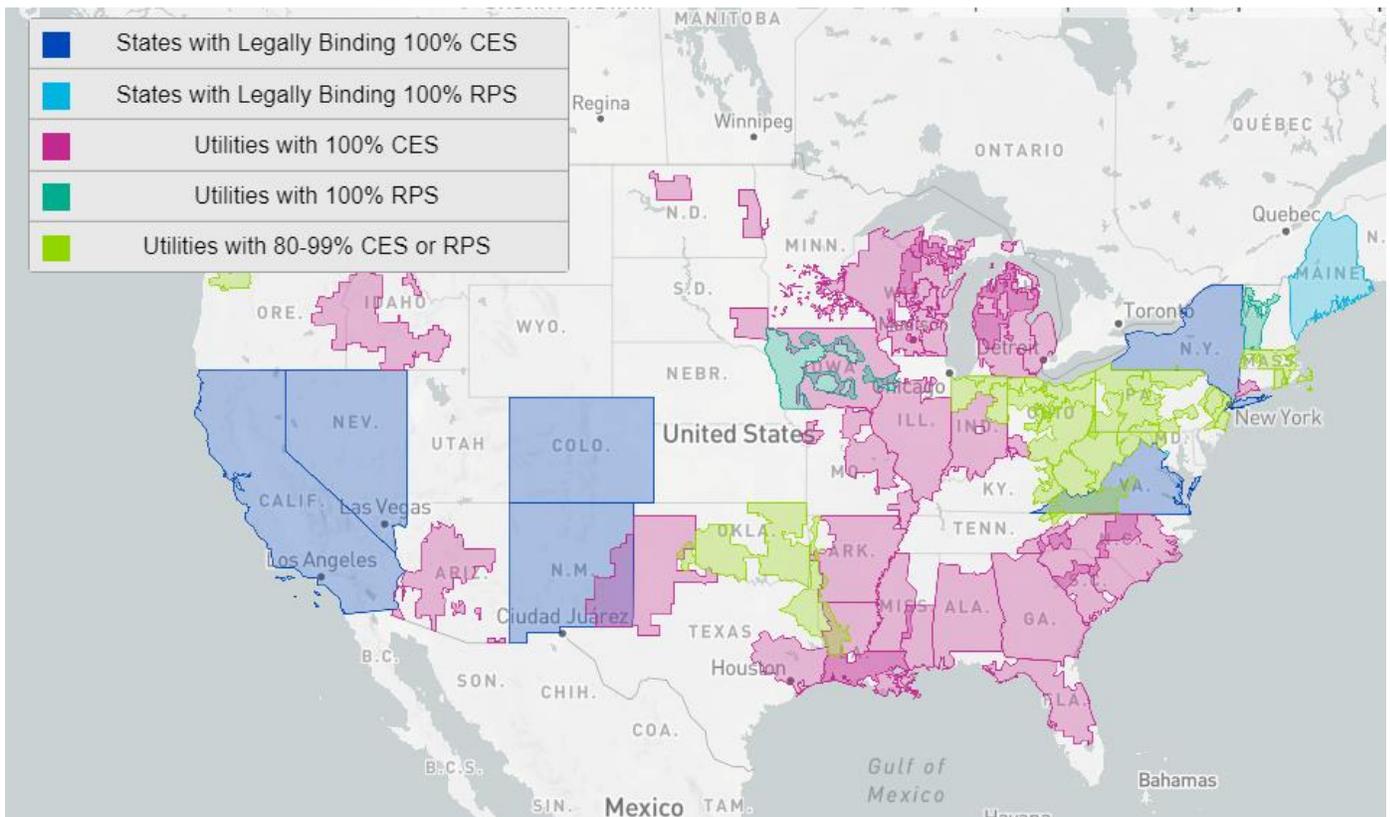
- Provide a clear vision for the requirements of advanced reactor fuel cycles
- Support programs that provide affordable and sufficient supplies of HALEU and support the development and/or expansion of commercial capabilities
- Pursue other action to support other fuel materials and types as needed
- Address the impacts of uranium mining in consultation with local communities
- Support development of multiple interim storage facilities to consolidate spent fuel storage
- Consider new approaches to fuel fabrication and fuel recycling using advanced technologies to reduce waste and potentially provide more economic fuel supply
- [Address long-term storage](#) by embracing consent-based alternatives, opening up waste for private sector innovations, and adopting other recommendations from the [Blue Ribbon Commission](#)

e. State Policy to Build New Reactors

Advanced nuclear energy offers states new technological options as they undertake energy transitions. Nuclear energy can provide local, well-paying jobs and supports the tax base for cities, counties, and states. While many states are making considerable progress on decarbonizing the electric sector, they must still decarbonize other sectors including heating and industry. Advanced nuclear reactors can support states' deep decarbonization efforts while establishing a new and innovative industry.

States have considerable energy decision-making authority and state-level policies can shape the deployment of advanced reactors in the United States. As states consider their decarbonization and energy goals, state policymakers are making plans and decisions about short- and long-term energy plans and governance. However, many states do not yet have policies that actively enable the construction and operation of advanced reactors. Some states have explicit restrictions on new nuclear power plant construction and/or taxes on spent nuclear fuel, but recently several states are reconsidering them. To facilitate demonstration and commercial reactor construction nationally, state policy should actively support or at least include advanced nuclear energy in broader carbon-free energy policies. State-level policy must also acknowledge and incorporate tribal, environmental justice, and labor concerns.

Figure 5. State and Utility Clean Energy Standards and Renewable Portfolio Standards



Source: [CATF](#)

States can provide attractive investment environments for advanced nuclear energy by:

- **Strengthening and broadening existing renewable portfolio standards to clean energy standards that include advanced nuclear energy**
- **Informing utility-level integrated resource planning (IRP) with sufficient data and engagement to plan for advanced reactors**
- **Providing resources for state-level decarbonization roadmaps and energy planning efforts to include advanced reactors**
- **Narrowing or removing [state restrictions](#) that inhibit advanced nuclear powerplant construction, either through state legislative action or by the Federal government establishing a permanent waste repository (the basis for 7 state restrictions)**
- **With input from local communities, ensuring that land use, economic, and other state-level regulation accommodates advanced nuclear energy**

f. Civil Society Participation and Inclusion

The nuclear energy industry and advocates need to break out of silos by engaging with other clean energy industries, the financial community, labor, environmental advocates, community leaders and energy stakeholders. As important as advanced nuclear technology is, it will only succeed if it has broad support and buy-in from customer and host communities. Broader support of nuclear energy is needed for advanced reactors to reach their full decarbonization potential, and the industry needs to earn that support. Advanced nuclear energy can help bring climate justice and environmental justice. Industry, advocates, and policymakers should actively engage, listen to, and address social and other concerns.

Societal recommendations include:

- **Efforts are needed to increase understanding of the benefits of nuclear energy**
- **A [social science research agenda](#), led by government-funding and academia, is important to build a basis for long-term commercialization that meets the real needs of communities**
- **Address the negative impacts of uranium mining and nuclear waste on disadvantaged communities by establishing and promoting ethical uranium standards**
- **Local community engagement and buy-in is crucial for all future nuclear projects and should begin as early in the project lifecycle as feasible**
- **Industry must create good jobs with high wages for construction, operations, and supply chain, boosting workers and local communities**

3. An Advanced Reactor Export Strategy for Global Leadership

Climate change and energy concerns are global issues and require international solutions. Nuclear energy is a major energy source for many countries and, by providing ~10% of electricity, is the #2 source of carbon-free energy worldwide, behind hydropower. American leadership in commercializing advanced nuclear reactors can accelerate international reductions in greenhouse gas emissions while also revitalizing U.S. exports and maintaining international nonproliferation, security, and safety standards. The largest share of carbon emissions growth is [projected to occur](#) in nations that do not currently use nuclear energy and suffer from [energy poverty and energy insecurity](#). Nuclear energy is an attractive option for its decarbonization, energy supply, and energy security characteristics. The innovation and entrepreneurial culture of the U.S. is uniquely suited to deliver commercial nuclear energy to new countries for [clean development](#).

While the U.S. has the most operating reactors of any nation, it has built few new domestic reactors since the early 1990s, with some existing plants retiring. This stagnation has reduced its international competitiveness and weakened its once robust supply chains. The U.S. risks missing out on an emerging market for nuclear energy that could be worth [\\$1.3-1.9 trillion](#) for electricity alone, with additional potential to provide zero-carbon heat, fuels, desalination, and other capabilities. Beyond economic losses, falling behind as a commercial nuclear exporter reduces the [influence](#) of the U.S. on global safety, security, and non-proliferation standards.

During this period of decades-long atrophy, [new competitors have emerged](#) and are poised to dominate global nuclear energy markets. Russia has emerged as the dominant international supplier of large reactors and their fuel. Russia is also the only country to have deployed a small modular reactor and commercial fast reactor. In the past 30 years, China has grown its domestic nuclear capability from zero to 49 nuclear reactors. It is looking abroad for new nuclear export markets, including among strong U.S. allies, and pursuing western regulatory approval for its technology to increase its export opportunities. In its pursuit of nuclear reactor deployments, it is leveraging its financing capability to obtain new-build projects for its indigenous design (the Hualong One) as well. China's overall nuclear energy program is part of its global economic and diplomatic strategy, including the Belt & Road Initiative (BRI).

As a general prerequisite to global competitiveness, the U.S. government and industry must actively decide to compete in global markets. Developing trade opportunities for nuclear reactors takes time, close coordination between government, allies, and industry, and attractive products built for foreign customers.

To develop global leadership in advanced reactor markets, priorities include:

- **Strengthening the positioning of the U.S private industry to compete against SOEs**
- **Assessing the global marketplace for the technology and encouraging the governance structure required for safe and secure export**
- **Elevating nuclear energy in U.S. foreign policy and clean energy diplomacy**
- **Developing a 21st century export control framework that enables American competitiveness and ensures non-proliferation commitments**

a. U.S. Technology and Export Competitiveness

As the U.S. contemplates how it will regain strength in the international nuclear market, it will face serious headwinds because Russia's and China's nuclear industries are state-owned and financed. Their governments provide significant funding for reactor R&D, customer outreach, construction, and export, as well as shape the risk tolerances of the constituent companies within the SOE structures. As SOEs, these companies are instrumental in supporting the technical and geopolitical objectives of their countries.

Recognizing its weakened position, the U.S. has [taken actions over the past several years](#) that have laid the foundation for an international nuclear revival. DOE's Nuclear Fuels Working Group created a strategy with initial steps to restore U.S. competitiveness. The Department of State introduced Nuclear Cooperation Memoranda of Understanding (NCMOUs), which have been followed by Intergovernmental Agreements (IGAs) in Poland and Romania. The U.S. International Development Finance Corporation (DFC) removed a ban on financing nuclear projects abroad. The Export-Import Bank (EXIM) created a letter of intent for \$7 billion in initial financing projects in Romania, to include work at Cernavoda.

These actions are just a beginning, and many additional measures are required to achieve renewed export leadership:

- **Creating a detailed assessment of Russian and Chinese nuclear reactor offerings and strategies, identifying the key characteristics and challenges, and proposing competitive strategies**
- **Identifying applicable lessons learned from China's and Russia's use of energy relationships for geopolitical leverage**
- **Disseminating information to U.S. companies about SOE models and guidance for competition**
- **Assessing past nuclear project missteps, characterizing the challenges, and developing solutions**
- **Assessing export projects that worked well and identifying conditions for success**
- **Considering new financing approaches and financial modeling scenarios that can support effective project structuring and execution**
- **Prioritizing sustained funding to support the export of domestically-developed technologies**
- **Identifying pathways and funding programs to provide early-stage programmatic and project-specific support to customer countries, including human resources development and training programs**
- **Coordinating with existing allies and democratic trading partners to [build multi-national deals](#) for newcomer countries**
- **Working with industry to establish a true "project developer" capability around advanced reactors**

b. Building International Institutions, Global Governance, and the Global Marketplace for Advanced Reactors

The era of the next generation of small modular and advanced reactors is emerging globally. These next-generation reactors will require new analysis of where they can be deployed overseas and revisions to the regulatory, governance, and programmatic development structures that were designed for the large LWRs. The potential market includes developing economy nations with small and distributed grids and desalination needs, as well as OECD nations that desire clean energy for expanded electrification, industrial applications, and hydrogen fuel production. Many of these non-OECD nations have minimal nuclear experience and will require significant international support to build their capacity to safely and securely operate nuclear reactors.

Internationally, the IAEA is the organization responsible for nuclear safeguards and nuclear security recommendations. It also has developed a Milestones Approach to assist countries contemplating nuclear energy. However, it has not yet adapted that approach for next-generation reactors. The OECD Nuclear Energy Agency (NEA) has created an advanced reactors expert group and it also serves as the Technical Secretariat for the [GEN IV International Forum](#) (GIF), a multilateral organization that has developed a methodology for Proliferation Resistance and Physical Protection (PR&PP).

The United States is also taking initial actions to support international governance and facilitate trade for advanced reactors. The U.S. and Canadian regulatory authorities signed an MOU to collaborate on next-generation regulations and both extended outreach to the United Kingdom. NNSA issued guidance for reactor developers that identifies the international requirements they will need to meet and has established internal working groups for safeguards and security. Expert non-governmental organizations also have provided [analysis](#) and [recommendations](#) on safeguards and security for advanced reactors.

The U.S. government, trading partners, multilateral organizations, industry, and others can build a strong international framework for advanced reactors by:

- **Using data-driven tools and analysis to understand the short- and long-term growth of the global civil nuclear market to identify policy priorities**
- **Providing early-stage programmatic and project-specific support for countries newly investing in commercial nuclear power**
- **Evaluating how the IAEA Milestones Approach should be modified to account for the characteristics of small and next-generation reactors**
- **Coordinating training, preparation, and other support from nations with nuclear power experience and expertise to build institutional and operational capabilities in newcomer countries**
- **Supporting the creation of a trusted information repository (including advisory capabilities) that can provide new nations with “off the shelf” documents, guidance, service providers, and related items**

- **Identifying how existing nuclear safeguards and security recommendations should be adapted for the next generation of technologies while maintaining rigor, including examining specific designs and fuel cycles**
- **Harmonizing international licensing requirements, processes, and supporting standards to promote reactor standardization and cost reductions**
- **Lifting prohibitions on nuclear energy finance by regional and international development banks and multilateral financing institutions**
- **Utilizing embassies to coordinate with potential customers and U.S. industry**
- **Expanding adoption of the Convention on Supplementary Compensation or other nuclear liability treaties to reduce global trade barriers**

c. Integrating Nuclear Energy into Foreign Policy and Climate Diplomacy

As the international environment has evolved, and America's competitors have gained greater international nuclear market share, it has become clear that the role of nuclear energy in U.S. foreign policy needs to be elevated and reinvigorated. The U.S. and some of its allies have inserted nuclear energy into the clean energy diplomacy process. Under the [Nuclear Innovation: Clean Energy Future Initiative](#), nuclear energy is now part of the discussion at the yearly Clean Energy Ministerial (CEM) meetings. However, nuclear energy has not been a central element of the discussions under the Conference of the Parties (COP) of the U.N. Framework Convention on Climate Change (UNFCCC).

Similarly, the U.S. and its allies have not engaged in a deep discussion about how they collectively [can cooperate to support advanced nuclear energy exports](#) and check the expansion of Russia and China. This is a complex area of diplomacy, finance, and national sovereignty that needs considerably more thought. But it is a discussion that should occur among key allies in the near term including the U.S., Canada, U.K., Japan, South Korea, and France.

U.S. foreign policy should continue to elevate the role of nuclear energy in U.S. foreign policy and clean energy diplomacy by:

- **Supporting competitive global energy markets that fairly meet the needs of emerging economies and including nuclear energy within trade agreements**
- **Ensuring that nuclear energy is included in the UNFCCC COP process as a zero-carbon energy source and a supporting technology for a decarbonizing energy system with a mix of resources**
- **Expanding the role of advanced nuclear energy in the CEM process and ensuring coordination between CEM and COP objectives and actions**
- **Promoting clean energy, including advanced reactors, as an essential development and economic growth strategy**
- **Encouraging the inclusion of nuclear energy within the European Union clean energy taxonomy to create access to clean growth development funds and other financing tools**
- **Promoting consideration of advanced nuclear energy as a critical energy source for industrial heating, desalination, and hydrogen production**
- **Intensifying engagement and cooperation with U.S. allies on technology collaboration, export financing, regulatory and licensing harmonization, and purchaser nation support**
- **Engaging as a multinational coalition with private sector finance entities to encourage expanded public-private financing of advanced nuclear projects**
- **Providing regulatory support from the NRC and other federal agencies for newcomer countries**

d. Modernizing Nuclear Trade and the Export Control Regime

A key aspect of non-proliferation policy is export controls to prevent the spread of nuclear materials and technologies to states that may pursue nuclear weapons. The U.S. originally developed its export control framework during the Cold War when there were a limited number of commercial nuclear exporters and limited trade in nuclear energy technologies. Today's global nuclear markets are different, with options from many different suppliers impacting the efficacy of unilateral export controls. Historically, leading nuclear exporters have the strongest [influence](#) on nuclear governance standards. The U.S. must remain an active participant in the global market by developing a 21st century export control regime that garners sufficient influence to support American non-proliferation leadership.

Although export controls have been effective, they can pose issues for international trade and American commercial competitiveness. Incremental steps have been taken toward the modernization and streamlining of the export control process, particularly in improving [Part 810 approvals](#) by DOE for export of commercial nuclear technologies. However, more progress and potentially transformative reforms are likely needed to modernize the U.S. export framework. Export controls and approvals must facilitate timely competitive trade, especially with U.S. allies that pose limited concerns regarding nuclear materials and technology. Reforming export controls to enable expanded trade can form the basis for multilateral systems to stop proliferation.

To reduce advanced nuclear trade barriers, Congress and U.S. federal agencies should:

- **Expand the use of nuclear cooperation memoranda of understanding as a means of engaging nations interested in nuclear energy, especially for developing economies and new nations considering commercial nuclear power**
- **Open markets for industry by proactively negotiating [123 Agreements](#) to enable export of American nuclear goods, services, and technologies**
- **Empower NNSA and other export control agencies with knowledge about the specific characteristics of advanced nuclear technologies**
- **Engage with existing and potential trade partners to continuously identify and reduce barriers**
- **Remove the blanket prohibition on foreign investment in American nuclear energy due to [AEA's FOCD provision](#), at least for U.S. allies**
- **Minimize other trade barriers between the United States and its closest nuclear trade partners (Canada, Japan, ROK, UK, France, etc.)**
- **Standardize international licensing to open markets**

4. Conclusion

Historically, U.S. leadership in nuclear science, technology, and engineering helped develop nuclear power into one of the world's leading clean energy resources. Despite recent stagnation in the competitiveness of the U.S. nuclear industry, advanced nuclear energy innovations promise to restore U.S. leadership. Fulfilling that promise depends on concerted action by industry, government, labor, and civil society. The potential environmental, economic and security benefits are vast, and there is much recent progress upon which to build. Time is of the essence to begin implementing this U.S. advanced nuclear energy strategy.

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